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MASTER OF MILITARY STUDIES

The Operational Effectiveness of Medium Caliber Airburst Munitions

SUBMITTED IN PARTIAL FULFILLMENT
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Abstract
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FORWARD

From June of 1997 to August 2000, the author worked as the Firepower Project Officer at the Direct Reporting Program Manager Advanced Amphibious Assault in Woodbridge, Virginia. During this period, the author tested and qualified the MK 44 30/40mm Automatic Gun and 16 various types of 30mm ammunition. Included in this test phase was a very rigorous lethality testing program. In addition, the author worked with multiple ammunition companies regarding their efforts with conventional and airburst munitions. In addition, a MK 44 Gun and Ammunition Integrated Product Team (IPT) was formed. Membership of the IPT was formed from all four services, DOD, domestic and foreign industry, and foreign governments.

Many of the ideas and concepts of this paper are based on the experience of the author as part of the IPT. The scenarios generated in the paper originate directly from requirements for AAAV and LPD-17. Some occur from work with other foreign and domestic program managers. Therefore, some information not footnoted in this paper is based on the author's experience from ammunition testing and working with many experts in the ammunition field.

I would like to thank LTC Steinar Amundsen from the Norwegian Army and currently a member of the Command and Staff College Faculty and Dr. Frankie Moore from Aeropredictions, Inc.for their guidance and advice they provided towards mentoring the author in this endeavor. The Direct Reporting Program Manager Advanced Amphibious Assault and NSWC Dahlgren were instrumental in providing advice and resources required for the completion of this paper. I would like to express my thanks to the many people who provided invaluable information and mentoring: Colonel Clayton Nans, USMC, Major Peter Cushing, USMC, Jim McConkie, Jeff Seiwert, Dave Neades, Matt Rosenblatt, Dave Barnhart, Tim Farrand, Gary Moshier, Gary Fleming, Dr. D.D. Jaya-Ratnam, Dave Broden, Bob Becker, Peter Gilles, Ed Daniels, John Sigler, Allan Buckley, Jan Hasslid, Bob Waterfield, Bob Glantz and many others that are members of the MK 44 Gun and Ammunition IPT.

The methodology proposed in this paper was presented at the NDIA 36th Annual Guns and Ammunition Symposium in San Diego, CA in April 2001. This paper provides a comprehensive view of the capabilities of medium caliber airburst munitions and several recommendations. However, this paper does not provide all the solutions for the problem. Both the paper and symposium presentation provide illumination of difficulties in evaluating the airburst munitions in the future. A proposal was made for an Airburst Symposium in June 2001 hosted by the AAAV Program to begin resolution of these problems utilizing interested government and industry expertise in and IPT environment. It is the author's intention to continue research towards providing resolution of the dilemmas and issues presented in this paper in future papers.

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EXECUTIVE SUMMARY

Title: The Operational Effectiveness of Medium Caliber Airburst Munitions

Author: Major Mark W. Richter, U.S. Marine Corps

Thesis: Determining the operational scenarios for medium caliber airburst munitions, current requirements, and current effectiveness methodologies and providing a recommended methodology that focuses on an effects-based analysis process.

Discussion: Airburst Munitions will provide an increased level of lethality to the U.S. military in the 21st century. There are several programs currently developing and testing airburst munitions in various medium caliber weapons. These weapons share one common target: threat infantry. It is important that the requirements and testing be linked with an effectiveness criteria that represents the way the munitions are intended to be employed. There are physical and mental effects associated with the evaluation of the munitions and these attributes should all be part of the evaluation process. Currently there is no common method of defining requirements that encompass all these attributes. At the same time, there is not a complete test methodology or models to support this effort.

Recommendation: This paper provides a recommended methodology utilizing an operational effects-based method of analysis. The approach encompasses the physical and mental effects combined into a scale that allows the munitions effectiveness to be catagorized utilizing multiple measures of effectiveness. There are several models that will support this process with some modifications. This methodology will also require changes in test methodologies. Based on these changes, requirements through live fire testing will be able to use the same criteria that reflects the munitions' total terminal effectiveness in operational scenarios.

ABSTRACT

The purpose of this paper is to explore how new platforms will utilize medium caliber airburst technology to increase the systems lethality on the battlefield. The two primary systems considered in this paper are the Marine Corps Advanced Amphibious Assault Vehicle and the U.S. Navy's LPD-17 Class of ships. The paper will present some of the current airburst concepts that are in development and also examine some of the current airburst program's requirements. The paper will then present scenarios where the target matrix provides specific engagement scenarios. These will include a diversity of targets. The paper will then focus on defining effectiveness criteria for evaluation of the different airburst munitions. The paper will specifically focus on measuring the effectiveness of airburst munitions against threat infantry targets. The paper will examine the current methodologies used to determine effectiveness and provide a recommended methodology using an effects-based analysis process. The paper then provides recommendations in several areas to support the effects-based analysis process.

LIST OF FIGURES AND TABLES

ABBREVIATIONS

AAAV	Advanced Amphibious Assault Vehicle
AHEAD	Advanced Hit Efficiency and Destruction
ALGL	Advanced Lightweight Grenade Launcher (STRIKER)
AMSAA	Army Material and Systems Analysis Activity (Aberdeen MD)
APG	Aberdeen Proving Grounds
APFSDS-T	Armor Piercing Fin Stabilized Discarding Sabot – Traced
APDS-T	Armor Piercing Discarding Sabot – Traced
ARDEC	U.S. Army Research, Development, and Engineering Command (Picatinney Arsenal, NJ)
ATD	Advanced Technology Demonstration
Alliant	Alliant Techsystems (U.S. ammunition manufacturer headquartered in Hopkins, MN with facilities in Radford, VA and New Brighton, MN. Operations in MN conduct the airburst effort)
Bofors	Bofors Ammunition
CASRED	Casualty Reduction model
DEA	Data Exchange Agreement
Diehl	Diehl Ammunition
DRPM AAA	Direct Reporting Program Manager Advanced Amphibious Assault (Woodbridge VA)
FUE	First Unit Equipped
HEI-T	High Explosive Incendiary – Traced
JLF	Joint Live Fire
JSSAMP	Joint Service Small Arms Master Plan
JTCG/ME	Joint Technical Coordinating Group / Munitions Effectiveness

Section I

If our Armed Forces are to be faster, more lethal, and more precise in 2020 than they are today, we must continue to invest in and develop new military capabilities…The global interests and responsibilities of the United States will endure, and there is no indication that threats to those interests and responsibilities, or to our allies, will disappear.[1]

Joint Vision 2020

The quote by the Chairman of the Joint Chiefs of Staff in *Joint Vision 2020* provides the vision to the services for the capabilities and requirements for warfighting in the future. The purpose of this paper is to provide an overview of medium caliber ammunition and associated weapon systems, to review capabilities and requirements in current airburst munitions programs, and then to focus on the critical issue of effectiveness- specifically effectiveness as it relates to threat dismounted infantry. The endstate is that the reader understands the advantages of medium caliber airburst munitions, visualize their employment relative to the threat target engagement matrix, and provide familiarity with the current trend of describing effectiveness requirements. In addition, this paper will provide an understanding of the difficulties and inconsistencies of effectiveness methodologies against threat infantry relative to live fire assessment criteria and actual operational employment. The goal is to provide a recommended methodology and criteria for measuring the effectiveness of medium caliber airburst munitions against land and waterborne targets with a focus on threat infantry. The potential applications of airburst munitions coupled with current and planned acquisitions of medium caliber weapon systems for the United States and our allies provides a significant enhancement to the lethality of the joint and multinational community of warfighters.

Introduction

Medium caliber ammunition is generally viewed as 20 millimeter (mm) through 60mm ammunition and is often referred to as minor caliber in the Navy. This size ammunition was first utilized in World War I and used extensively in World War II. The primary purpose for medium caliber in its infancy was in an anti aircraft role. In ground applications, its early use was on lightly armored vehicles. The Soviet BMP family of vehicles utilizes 30mm ammunition for its main armament. The United States Army Bradley Fighting Vehicle and the United States Marine Corps Light Armored Vehicle utilizes the Bushmaster 25mm Chain Gun as its primary armament. Medium caliber came of age in the aviation community with 20mm ammunition and currently NATO forces use 20mm, 25mm, 27mm, and 30mm in a variety of guns on various aviation platforms. The naval application of medium caliber has been very diverse. The United States Navy utilized medium caliber in an anti aircraft role in World War II through Vietnam. The advent of radar tracking in conjunction with a high volume of fire gatling gun gave rise to the U.S. Navy's Phalanx system which uses 20mm ammunition and the United Kingdom and Dutch Navy's Goalkeeper systems which use 30mm ammunition. In an effort to combat high-speed attack boats, the Navy mounted the 25mm Bushmaster gun on a MK 36 pedestal mount during Operation Desert Storm.

Medium caliber ammunition has improved over time. Harsh requirements from the Gatling gun community coupled with the environmental requirements of the aviation community have enhanced the ammunition. Increased ground anti armor lethality requirements in the 1990's gave rise to high performance armor piercing ammunition.

[1] Joint Chiefs of Staff, *Joint Vision 2020* (Washington, DC: GPO, June 2000) 1

Technological advances created airburst munitions in an anti aircraft role. Oerlikon Contraves Pyrotec in Switzerland created a system called Sky Shield and Sky Guard utilizing a programmable airburst technology in a 35mm cannon. Bofors in Sweden created a 2P and 3P fuze that has an airburst and/or proximity fuzed in 40mm. But these advances were still primarily focused at aviation targets. This airburst technology has transitioned into ground vehicle applications.

The role of medium caliber in ground forces has changed in the last several years. Today, the role of medium caliber for the Marine Corps' Advanced Amphibious Assault Vehicle has threat infantry as the primary target vice the traditional armor target. In this role, hit probability and infantry casualties become the primary criteria for the weapon system. The Navy views the small boat threat as a critical vulnerability to the fleet in which a highly accurate fire control system coupled with the increased hit probability of airburst munitions provides an improved defensive capability for naval force protection.

Why Airbursting Munitions

Current conventional medium caliber high explosive ammunition either functions in a Point Detonating (PD) mode or a Point Detonating Delay mode. Against infantry targets such as a squad, the technique of fire is to place the round in the squad area with a detonation initiated by the ground, trees, buildings or other solid objects. The resulting fragmentation pattern then creates a lethal area within the squad area causing casualties. The lethal area is dependent upon several key aspects relative to the target area. These are the ranges to the target, angle of fall of the projectile, composition of the impact material at point of impact, and the type of ammunition fired. Changes in these parameters will change the lethal area footprint relative to the individuals in the squad. A difference of

the terminal effects of the ammunition is less noticeable on vehicle, material, and urban targets, although range does have an effect on some types of ammunition at longer ranges. But generally, the effects are repeatable with each round fired.

Testing of an array of various targets can provide the terminal lethality characteristics of a particular type of ammunition against a specific target when based on an operational scenario. However, similar testing against infantry squad size targets presents a much more difficult dilemma in the analysis process. The effects of a projectile can vary widely in the squad area due to normal random variations in the point of impact of the projectile. This randomness can be attributed to the normal dispersion of the weapon system, fire control error budgets, and atmospheric effects in the external ballistic cycle. The cumulative effects can create different points of impact that can make comparative and discrete analysis of actual test results difficult. The same results are not repeatable round after round. The proposed methodology in this paper regarding testing against infantry targets may alleviate this problem to a certain extent. This proposed methodology will also present criteria that is often not considered in the effectiveness evaluation.

Why use an Operational Effectiveness Based Analysis?

Operational effects-based approaches are currently used in various contexts in the U.S. military today. The Joint Warfighting Analysis Center (JWAC) at NSWC Dahlgren uses effects-based targeting. This group focuses on analyzing the effects desired against an enemy and then providing the recommended target and weapon system to provide these effects. One example of this was the targeting of key nodes of the power grids in Belgrade to erode public support of Milosvic. Effects based operations are currently

being included in the miltary's operational doctrine. The Marine Corps has adopted this in their new operations publication. In this context, the operations conducted are planned for a desired effect against the enemy.

Based on these examples, it seems reasonable that an operational effects-based analysis of medium caliber airburst munitions would best characterize the munitions operational scenario effectiveness. This methodology then provides a format to prepare requirements, create development criteria, and operational testing that reflects the operational requirements. In addition, characterizing the munitions performance in this manner also ensures it meets the purpose in which the munition will be used. I propose that the definition to be used in regards to threat infantry be the following.

The criteria and requirements for airburst munitions that encompass the physical and mental effects desired against the enemy when viewed from an operational perspective. With this, it is essential to identify the operational scenarios, the objective effects that are desired or required on the target, and what is the objective of the engagement.

By adopting an effects based methodology, all the characteristics associated with a munition are then evaluated. However, this will require changes in the current methodologies used today.

Section II
Scenarios

Infantry Targets

The infantry target scenario is based on the standardized eight-man squad. The size of the squad reflects typical European size squads. There are several variables regarding an infantry squad. The first is the posture of the squad, are they offensive or defensive. Are they standing, kneeling, or prone? The second is the environment the squad is operating in. Is it open terrain, wooded, agricultural, urban, etc? These first two factors then usually determine what type of tactical formation the squad is in and the size of the squad area footprint. In modeling situations at AMSAA, the squad is usually placed in a 10 meter by 50-meter area. The squad is normally positioned in an open terrain setting in either a standing or prone position.

Another tangible criterion for the infantry squad is the level of personal protection the soldier is wearing. This level of protection can range from none, to helmets only, to helmets and flak jackets. The usual standard for testing in the United States is the current issue Kevlar helmet and the Kevlar PASGT vest commonly referred to as flak jacket. However, there are many new advances in the U.S. and abroad regarding personal protection. The U.S. Marine Corps recently adopted the Interceptor vest that will be fielded in 2005 timeframe. This vest can be changed to different levels of protection. The CRISAT vest has been introduced in the United Kingdom for use and features ceramic armor plates that can be changed to different levels of protection as well. The Former Soviet Union has a protective vest with titanium plates that was used in Afghanistan. The

question then becomes, what level of personnel protection should the ammunition be required to defeat? Should the requirement be for the most prolific protection worldwide or based on small scale, high performance protection? The answer to this question lies within the predictions of the intelligence community on future infantry threat capabilities. All of these are considerations that must be taken into account and decisions made for requirement, design, and testing purposes.

Infantry Target Scenario for AAAV

An infantry target scenario for the AAAV is an eight-man threat squad in a formation at 1500 meters and 2000 meters from the vehicle. The infantry are protected with the standard PASGT vest and Kevlar helmet. The gunner then must detect and identify the target as an enemy threat. The squad, for modeling and lethality testing, is usually positioned in fire team wedge, squad column formation. During lethality testing of conventional 30mm ammunition for AAAV, the direction of fire was typically along the long axis of the squad to increase the hit probability within the 10 x 50 meter area. For conventional ammunition, this is the preferred scenario. But in reality, a squad could be oriented in various directions from the gunner. In order to effectively correlate with the AMSAA modeling effort and comparison with other conventional and airburst programs, it would be beneficial for the threat infantry squad to remain constant. However, the effectiveness should ultimately be tested from other orientations as well.

ATGM Site

The Anti Tank Guided Missile scenario is depicted as a three-man squad in a concealed position at a maximum range of 4000 meters from the AAAV. The representative missile used for this scenario is the AT-10 and has a 5 km range.

The scenario would assume that the MAGTF is aware of the threat capability and that the AAAV crew is aware of the threat possibility within their battlespace. The scenario would then assume that someone in the force observed the missile launch and that one of the AAAV's, not necessarily the one targeted, is able to engage the threat missile launch. The last assumption is that the back blast from the launch remains detectable for several seconds. The criteria is then the ability to acquire the target area and fire, Time of Flight (TOF) for the projectile to reach its burst point at the target, and then effectiveness on the target. The primary goal of this engagement is to prevent the missile from achieving a successful hit. The key criteria for the airburst munition is the time it takes to set the required information in the fuze, TOF, and effectiveness at the target. The key word in this phrase is "effectiveness" for this scenario. This could range from suppression to incapacitation of the gunner or entire team. For this scenario, the same criteria as infantry would apply.

With the advent of newer ATGM's, this scenario could perhaps become obsolete or would require a change in the Tactics, Techniques, and Procedures. For example, engaging a Fire and Forget ATGM similar to the current Javelin system in U.S. forces would have no adverse effect on the missile after launch if the firing team were engaged. This change would require a change in the TTP's for the employment of airburst munitions against fire and forget ATGM's. The new technique may be to have an airburst point 500 meters away from the AAAV along the flight path of the ATGM. For this scenario, assume it is the AAAV being engaged. This defensive maneuver may be enough to disrupt the seeker head or pierce the missile with fragmentation, thus preventing impact on the intended target. The whole scenario may become obsolete with

the advent of Directed Missile Countermeasure Devices (DMCD), which is already a Preplanned Product Improvement (P3I) for AAAV. However, based on the DCMD's spectrum of performance against ATGM threats, the scenario may still remain when older generation wire guided ATGM's are encountered.

Given this scenario, crew performance is as critical or more critical than the effectiveness of the airburst projectile itself. This should then require a peacetime training scenario to ensure crew proficiency.

Light Armored Vehicles

The Light Armored Vehicle (LAV) target is a Former Soviet Union (FSU) BTR class vehicle. The scenario for this engagement would be a one on one engagement at 1500 meters (O) and 2000 meters (T). The effectiveness criteria would be to determine the quantity of rounds for a mobility kill, firepower kill, or total kill of the BTR. The current conventional ammunition meets this requirement for AAAV. The current AAAV ORD requirement requires a Probability of Hit in 6 rounds fired.[2] The airburst munition does offer several advantages in this scenario over conventional ammunition. The advantage is flexibility within certain Rules of Engagement (ROE). For example, instead of using a point detonating delay mode in the engagement, it may be more advantageous in a given situation to blind all of the targets optics with airburst fragmentation. Thus, given a possible stricter ROE regarding killing threat vehicles, the threat may be blinded so he can no longer move and can no longer fire using his optics thus negating the need for personnel casualties within the BTR. Certainly this engagement scenario could be considered suppression or degradation to the BTR. An alternative capability, although

[2] Direct Reporting Program Manager Advanced Amphibious Assault, "Operational Requirements Document for Advanced Amphibious Assault Vehicle" 2000

not preferred, would be to use this same method of engagement as a self-defense measure against armored threats. For example, the blinding of tank optics could be used as a last resort defensive measure.

Within the LAV scenario, there is really no need to include a BTR in a defensive position. The reason for this is some other asset within the MAGTF can engage a static vehicle in the defense. The argument may be countered by the determination that it was not engaged and destroyed. If it is in hull defilade, the target will certainly have a much lower probability of hit. But the same argument applies to conventional munitions as well. The airburst round would have the same probability of hitting the BTR in a Point Detonating Delay mode as conventional munitions but also offers increased hit probability potential in the ability to blind him in the defense.

Urban/MOUT Environment

The Urban/MOUT scenario has the potential for multiple variations. However, not every scenario can be applied, as it would be an endless task. The logical steps in this scenario are to determine what are the likely urban structures and structural materials to be encountered, the primary threat weapon systems from the urban area to engage the AAAV, and the mission. The best source for the first part of the question is Dr. Richard Ellefson's report "Current Assessment of Building Construction Types In Worldwide Example Cities."[3] From this document and recommendations from urban specialists, three urban materials were selected for AAAV. These were eight inch thick reinforced concrete wall, triple brick concrete wall, and brick on block. While this does not represent every possibility, it represents what would be most typical of the high to mid

[3] Ellefsen, Richard, "Current Assessment of Building Construction Types in Worldwide Example Cities" 1999

spectrum of target material. The second part of the question is to identify the most lethal primary threat weapons within the urban area. For AAAV, this was considered to be RPG's and thus the preferred engagement range was determined to be 1000 meters from the structure. The third part of the question was the mission. The primary mission of the AAAV's firepower is as a fire support platform for dismounted infantry in the urban environment. The effectiveness criteria in this effort with conventional ammunition was to determine how many hits were required to create a man size opening through the wall. In going through a wall, Point Detonating Delay ammunition, such as the Multipurpose, performed the best. For example, the MPLD-T could create a man size hole in the brick on block target with four hits and triple brick with nine hits. If the enemy were in the room behind the wall, there were multiple effects to evaluate. There was fragmentation from the projectile, fragmentation and flying blunt debris from the wall material, dust from the wall, blast effects, and noise. The interior effects were extreme. The effectiveness of an airburst munition would need to achieve similar results. The desire should be to breach the wall and reduce all the personnel in the room to combat ineffective.

Other airburst systems require an ability to go through the window of a building and detonate inside the room. This could present several challenges. First, does the laser range finder recognize the glass or the far wall as the burst point? If it is purely an open window with no glass, does the laser range finder then recognize the far wall of the room or the adjacent exterior wall next to the window as the burst point? Second, is it easier from a hit probability standpoint to go through the wall adjacent near the window? Is the objective to minimize collateral damage in the urban area?

Bunker Targets

Man made fortifications have been around since defenders occupied castles. Current doctrine embraces attacking enemy weaknesses or critical vulnerabilities. However, a critical vulnerability may be defended by mutually supporting bunkers. The fact it is immobile provides the MAGTF with multiple options for engaging the target. However, it can be envisioned that a bunker could still exist that requires the attacker to eliminate it with organic weapons.

Since bunkers can come in all shapes and sizes, the Redstone Technical Test Center has selected the 8 foot by 8 foot Soviet Earth and Timber Bunker as the representative target for bunkers. This bunker represents the high survivability spectrum of bunkers on the battlefield. The bunker is composed of 6 inch by 6 inch lag bolted timbers for the interior structure with 18 inches of loose fill in between a double layer of sand bags.

During testing at Redstone Technical Test Center, the Soviet Bunker was engaged at a 45-degree aspect to the gun target line at a range of 600 meters with 30mm MPLD-T ammunition. The focal point for the engagement was the front aperture where the weapon would be located. The 30mm MPLD-T ammunition was able to collapse the aperture support structure after 11 rounds resulting in a mission kill of the bunker. The bunker target was also tested at Eglin AFB with a direct side engagement at 600 meters using a kinetic energy approach. The 30mm APFSDS-T was able to penetrate into the interior of the bunker with considerable effectiveness. The lesson learned was there are two ways to defeat a difficult bunker target.

For airburst munitions, the requirement may be to collapse part of the structure as the MPLD-T did with the conventional ammunition or the ability to suppress the bunker by airbursting fragmentation in front of the aperture, which allows other forces on the battlefield to maneuver to kill the target. Since this target does represent the high level of protection, the ability to suppress the target should be the evaluation criteria. The determination of suppression as far as the munition's effectiveness will be discussed in detail later in the paper.

Material Targets

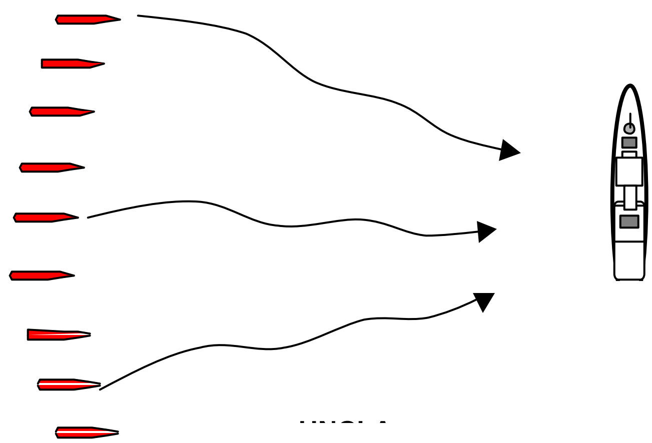
Material targets are a very diverse category. These targets are trucks, vehicles, logistical assets, and other similar types of equipment. The effectiveness criteria for these types of targets are that they would not be mission capable for their intended purpose. The range to the target would preferably be in excess of 2000 meters. A target that has often been included in other requirements is the FSU GAZ 66. This vehicle is usually selected for two reasons. The first reason is for the probability of hit determination and the second reason is for the damage effects analysis. However, in an asymmetric threats environment, we have seen "technical vehicles" in Somalia with weapons mounted that were a direct threat. The hit probability criteria may well be suited then for the smaller Toyota pickup truck type target.

Waterborne Scenarios

The scenarios involving waterborne targets are applicable to nearly any surface platform. These platform classes include LPD-17, DD-21, DDG-51, LHD-7, CVX, PC-1, U.S.C.G. Deep Water Program, as well as many other domestic and foreign class ships requiring a Close In Gun System (CIGS) for ships self defense against the small boat

threat.[4] In addition, the scenarios involve targets that the AAAV could become engaged with during waterborne surface maneuver. However, the AAAV has several attributes that the larger vessels of the naval fleet do not have. The AAAV has speed, maneuverability, small size, and operates in numbers that can overmatch a threat.

The U.S. Navy currently does not have a capable defense against the small boat threat that may swarm a ship. An NDIA study that is still in draft discusses in detail the Navy's deficiencies and requirements. The threat will be divided into three classes: craft up to 18 feet, craft 18 feet to 30 feet, and craft over 30 feet.



KEY ASSUMPTIONS

- **No Area SUW Support and Threat not Countered by Theater SUW Forces**
- **Threat: Massed Small Boat**
  - **10 - 20 Boat raid**
  - **Speed > 30 kts, maneuvering**
  - **Spread over 20° - 60° azimuth**
  - **Simultaneous arrival**
  - **Short-range, weapons (< 1kyds)**
- **USN Ship Capabilities**
  - **Detection range supports weapons (not clutter limited)**
  - **Adequate ID capability (surface picture, doctrine, training, etc.)**
  - **Well trained crew: systems perform as advertised**

<u>Craft 30 Feet and Over</u>

The objective craft in this class is the Boghammer Fast Attack Craft. This craft has good speed, maneuverability, and an aluminum hull. It can be outfitted with any array of weapon systems to include heavy machine guns, ATGM's, and RPG's. This is the highest-level threat in this class.

[4] NDIA Study

Craft 18 to 30 Feet

The typical craft in this class is a Boston Whaler type craft. This craft is highly maneuverable, can carry an assortment of weapons, and can be operated by a minimal size crew down to one person. The real danger is the tactics employed by these craft are to attack in numbers overwhelming the ships defense capability. The most dangerous craft in this class is a suicide boat with intentions to inflict damage much like the U.S.S. Cole suffered in Yemen.

Craft Less than 18 Feet

The typical craft in this class is a jet ski or other small personal watercraft. These are very fast, very maneuverable, and small. These characteristics result in a very difficult control solution and low probability of hit. This craft's most dangerous weapon is an RPG or suicide craft.

The Threat Ring

All these targets then create a threat engagement ring around the ship. The critical factors are stopping the craft before it can get inside its engagement envelope. The anticipated threats keep out range for these craft are:

Boghammer – 3000 yards
Boston Whaler- 1000 yards
Jet Ski- 600 yards

Helicopters, Slow Moving Aircraft, and Remotely Piloted Vehicles

Although not a required target for AAAV, many Infantry Fighting Vehicles do have the requirements to engage attack helicopters. The usual threat helicopter is the HIP. With the current digital fire control systems and conventional 30mm MPLD-T ammunition, the capability to accomplish this mission has been demonstrated. However,

an airburst round will increase the hit probability on the helicopter, especially if it has an electrostatic sensor capability imbedded in the fuze. Although not a current target, the RPV may be a high threat target as well. Based on the U.S. employment, the RPV can relay real time targeting data to a shooter. Since most of this technology is COTS, it is reasonable to assume that the enemy in the near future will have this capability as well in nearly every theater. The RPV is also a capability that does not require air superiority, is low risk, and there is very little defensive capability against RPV's other than Electronic Warfare. This may be the highest payoff target for airburst munitions in the future.

Indirect Fire

The possibility exists that with the advanced fire control systems being fielded in the near future, an indirect fire capability could be incorporated into a medium caliber weapon system. The dilemma in this scenario would possibly be the requirement for a proximity capability in the fuze. Another area that supports the indirect fire concept is a technological advance in compensating for atmospheric effects on external ballistics to the target and introducing them as corrections in the fire control computer.[5] Success in the indirect fire area could create the possibility of using only time as the airburst functionality vice using proximity.

The AAAV Program did a limited investigation into the indirect fire functionality and it was determined it would be feasible if required. The scenario would follow that the AAAV Platoon Commander would receive a call for fire from an infantry unit who would provide the target coordinates and target description. The coordinates would then be entered into the AAAV fire control computer. The fire control computer would

[5] Note-AAAV has a current SBIR addressing these issues

interface with the rest of the AAAV information systems where it would have its GPS location, the elevation for both the AAAV and the target, and the cant angle for the vehicle. The super elevation and azimuth would then be computed as well as the latest meteorological data and atmospheric effects. With a platoon of 12 AAAV's responding to this fire mission, the platoon commander would then issue the order for a ten round burst on the target and 120 rounds are on the way in a very short period of time. A feasibility test was conducted with the MK44 Automatic Gun and 30mm HEI-T ammunition and the rounds were gyroscopically stable in flight as predicted in PRODAS and based on actual firing. The range of current HEI-T is out to 8500 meters.

There are several possibilities to overcome time of flight issues. One method is a string of pearls on the target, which in effect would select the optimal airburst time, and then add incrementally to each round a few milliseconds. For example, the first projectile may have a time which airbursts it at 50 meters over the target, the next 40 meters, the next 30 meters, the next 20 meters, and the next 10 meters, and the next five point detonate on the ground. This is only an alternative solution if all the error budget of the time of flight of the projectile cannot be resolved technically or financially.

Section III

Similar Airbursting Systems in Development

Objective Individual Combat Weapon (OICW)

The OICW is a man portable, dual munition system capable of firing 5.56mm kinetic energy projectiles and 20mm High Explosive Airbursting Munitions.[6] The Program Manager was the Joint Service Small Arms Master Plan (JSSAMP) during the Advanced Technology Demonstration (ATD) with PM Small Arms fulfilling the PDRR and EMD phases of the acquisition process. The system utilizes a laser range finder accurate to within one meter at 1000 meters and a day/night fire control system. The objective of the system is a more lethal one-man portable weapon system with better-combined capabilities than the individual capabilities of the M-4, M-16, and M-203. The 20mm round is a High Explosive Airburst utilizing a turns count fuze concept. The primary target for OICW is personnel. These are point targets such as a single soldier or area targets such as a group of soldiers. These targets may be postured as standing, crouching, kneeling, sitting, and prone positions. These targets may be fully exposed or in defilade.[7]

OICW Lethality Requirements

The lethality requirements of OICW as expressed in the ORD are as follows:

Airburst Function

Point Targets- $P_{(i)}$[8] of not less than 0.5 to 500m day or night (T)
$P_{(i)}$ of not less than 0.9 to 750m day or night (O)

Defilade Targets- $P_{(i)}$ against an individual soldier of not less than 0.35 to 500m

[6] Note- The contractor for OICW is a team formed by Alliant Techsystems, Heckler and Koch, Dynamit Nobel, Brashear Systems, and OCTEC.

[7] Note- OCSW ORD defines a defilade target as a soldier using battlefield cover and concealment whether standing, crouching, prone , or in a foxhole.

[8] Note- $P_{(i)}$ is Probability of Incapacitation. Additional information is contained in Section 4.

day or night(T)
$P_{(i)}$ against an individual soldier of not less than 0.9 to 500m day or night (O)

Area Targets- probability of incapacitation given one shot $P_{(i/s)}$ engagement per man against the target dismounted threat squad of not less than 0.5 to ranges of 1000m day or night (T)
probability of incapacitation given one shot $P_{(i/s)}$ engagement per man against the target dismounted threat squad of not less than 0.9 to ranges of 1000m day or night (O)

Point Detonating Function

Unarmored Vehicles- capable of damaging/suppressing an unarmored vehicle with a probability of hit P(h/s) against the target threat vehicle of not less than 0.75 to 500m day or night (T)

- capable of damaging/suppressing an unarmored vehicle with a probability of hit P(h/s) against the target threat vehicle of not less than 0.9 to 1000m day or night (O)

Point Detonating Delay Function

Lightly Armored Vehicles- capable of damaging/suppressing an unarmored vehicle with a probability of hit given a shot P(h/s) against the target threat vehicle of not less than 0.75 to 800m day or night (O)

Helicopters- capable of damaging a hovering helicopter aircraft with a probability of hit given a shot P(h/s) against the threat aircraft (FSU Mi-HIP Assault Class Helicopter) of not less than 0.75 to 1000m day or night (O)

High Explosive (HE) – have a lethal area radius from the munition's burst point against protected standing, exposed target to ensure a 0.75 P(i) (T) defeat level 4 threat body armor, exposed target to ensure a 0.75 P(I) (O).

Other Critical Requirements

Target Acquisition/Fire Control System (TA/FCS) – provide a 0.9 probability of recognition given a detection (Pr/d) of personnel (upright moving, tactically deployed) and operating vehicle targets (BTR-90) out to a range of 1000 meters in clear air day or night[9] and to 750 meters in obscurants[10] (T).
Thermal Capability- provide a 0.9 probability of recognition given a detection (Pr/d) of personnel (upright moving, tactically deployed) and operating vehicle targets (BTR-90)

[9] Note- Clear air is defined in the OICW ORD as atmospheric conditions that provide seven kilometer visibility along an unobstructed line of sight
[10] Note- Obscurants are defined in the OICW ORD as white phosphorous (WP), hexachloro-ethane-zinc oxide (HC), smoke (CL=2), and moderate rain, fog, and snow

out to a range of 1100 meters in clear air and 750 meters in obscurants (T) and 1100 meters in obscurants (O).

Laser Range Finder- accurately determine range to the target (+/-) 1 meter in battlefield obscurant environments of dust and smoke off a 12 percent reflective target in a cluttered scenario out to 1100 meters (T).

Rationale for an Individual Weapon with Airburst Capability from OICW ORD

"The current family of small arms such as the M-16, M-4, M-203, and M249 lack the desired range and accuracy to defeat exposed and defilade individual and group targets to 1000 meters. With a Probability of Incapacitation of 0.50, this equates to more than 500% increase P(I) over the baseline system. Across offensive and defensive scenarios, blue forces sustained 80+ percent reduction in losses and increased threat losses by 25+ percent when equipped with the OICW systems. The ability to engage defilade targets contributed to 20-40 percent of the threat kills. Of the total threat kills, 40-45 percent were attributed to multiple target kills with a single round. The analysis shows the OICW system to be more cost effective than the baseline system, cost per operational mission is reduced, and cost per threat kill is reduced. It provides a day, night, and battlefield obscurant capability as well as additional benefits."[11]

Objective Crew Served Weapon (OCSW)

The OCSW is a two man portable, ground mounted crew served weapon system capable of firing 25mm High Explosive Airbursting ammunition, Armor Piercing ammunition, and Target Practice ammunition.[12] The system utilizes a laser range finder accurate to within one meter at 2200 meters and a day/night fire control system. The objective of the system is to provide a system with reduced weight, improved hit probability, and increased effectiveness over the current crew served weapons that include the M240 7.62 Medium Machine Gun, MK19 40mm Grenade Machine Gun, and the M2 .50 Caliber Heavy Machine Gun. The mission is increased effective suppression that will enable unit maneuver and increased firepower. The primary target of OCSW is to defeat threat protected personnel. Like OICW, These are point targets such as a single

[11] Joint Service Small Arms Program "Draft Operational Requirements Document for the Objective Individual Combat Weapon" 4 March 1999,

soldier or area targets such as a group of soldiers. These targets may be postured as standing, crouching, kneeling, sitting, and prone positions. These targets may be fully exposed or in defilade.[13] The secondary target is self defense against unarmored / light armored vehicles and against slow low flying/ hovering aircraft.

OCSW Lethality Requirements

The lethality requirements of OCSW as expressed in the ORD are as follows:

Airburst Function

Point Targets in Defilade- probability of incapacitation equal to or greater than 0.75 given a three shot (three round burst) engagement against a protected, prone defilade man size target out to 1000 meters.(T)

- probability of incapacitation equal to or greater than 0.9 given a three shot (three round burst) engagement against a protected, prone defilade man size target out to 1000 meters.(O)

Area Targets- probability of incapacitation of 0.75 given three, three shot engagements against a protected 8 man squad to 2000 meters.(T)

- probability of incapacitation of 0.9 given three, three shot engagements against a protected 8 man squad to 2000 meters.(O)

Armor Piercing (Point Detonating)

Unarmored Vehicles-capable of damaging to defeat or suppress FSU GAZ-66 class unarmored vehicles given a probability of hit (Ph) of equal to or greater than 0.75 for a three shot engagement (three round burst) out to 1000 meters.(T)

Light Armored Vehicles- capable of damaging to defeat or suppress a FSU BTR-90 class lightly armored vehicles given a P(h) of equal to or greater than 0.5for three shot engagement (3 round burst) at 1000 meters (T)

Slow/Hovering Low Flying Aircraft- capable of damaging to defeat or suppress a FSU MI-HIP Assault Helicopter class aircraft target given a P(h) of equal to or greater than 0.5 for a three shot engagement (3 round burst) to 1000 meters. (T)

P3I- insert page 8 info

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[12] Note-The contractor for OCSW is a team formed by GD Armament Systems and Primex Technologies.

[13] Note- OCSW ORD defines a defilade target as a soldier using battlefield cover and concealment whether standing, crouching, prone, or in a foxhole.

Other Factors

Target Acquisition/Fire Control System (TA/FCS) – provide a 0.9 probability of recognition given a detection (Pr/d) of personnel (upright moving, tactically deployed) and operating vehicle targets (BTR-90) out to a range of 2200 meters in clear air day or night[14] and to 1100 meters in obscurants[15] (T).

Thermal Capability- provide a 0.9 probability of recognition given a detection (Pr/d) of personnel (upright moving, tactically deployed) and operating vehicle targets (BTR-90) out to a range of 2200 meters in clear air and 750 meters in obscurants (T) and 1100 meters in obscurants (O).

Laser Range Finder- accurately determine range to the target (+/-) 1 meter in battlefield obscurant environments of dust and smoke off a 12 percent reflective target in a cluttered scenario out to 2200 meters (T).

Advanced Lightweight Grenade Launcher (ALGL) – STRIKER

The Striker is a two man portable 40mm automatic grenade launcher which uses a laser range finder and a video image processor coupled to a fire control computer to increase hit probability. The main purpose of Striker is to provide a man portable, lightweight substitute for the MK19 automatic grenade launcher. Striker can fire the same ammunition as the MK19 as well as an airburst 40mm grenade.[16]

The Strikers Lethality Requirements are:

Programmable HE ammunition will detonate and distribute fragments in a 100 square meter area to the rear of the point burst with the following threshold fragmentation densities:

Fragments must penetrate a 1.5 mm plate of St 37 mild steel, with 95% coverage of 3 meters from the point of burst, with a fragment density of our penetrations per square meter.

Fragments must penetrate a 1.5mm plate of mild steel at a distance of 5 meters from the point of burst, with a fragment density of 1.5 penetrations per square meter with 70% coverage.

[14] Note- Clear air is defined in the OCSW ORD as atmospheric conditions that provide seven kilometer visibility along an unobstructed line of sight

[15] Note- Obscurants are defined in the OCSW ORD as white phosphorous (WP), hexachloro-ethane-zinc oxcide (HC), smoke (CL=2), and moderate rain, fog, and snow

[16] SACO Defense Incorporated. Brochure with CD and Videocassette. *Striker 40mm Advanced Lightweight Grenade Launcher (ALGL)* n.d.

Programmable High Explosive Dual Purpose ammunition will detonate and distribute fragments in a 200 degree hemispherical pattern and must penetrate a 1.5mm plate of mild steel with 95% coverage of 3 meters from the point of burst with a fragment density of penetrations per square meter.

Fragments should penetrate 1.5mm plate of mild steel at a distance of 7.5 meters from the point of burst with a fragment density of at least 1 penetration per square meter with 70% coverage.[17]

Requirements Comparison

OICW, OCSW, and Striker have a primary target requirement to defeat protected infantry in the open and in defilade. All three are replacing current, proven legacy systems. The increased capabilities of these three weapons reside in the fact they are lighter, have laser range finders and fire control computers, and have an airburst projectile capable of defeating multiple targets. The increased effectiveness of these systems allows for savings in the quantity of ammunition required to defeat a target. This reduction in ammunition quantity is then realized as a logistics savings through the transportation system to the load the individual soldier carries during his mission. The premise is, the more lethal the munition and the higher the hit probability, the less cost and support needed on the battlefield.

Lethality and Other Issues

The lethality issue becomes a dilemma as the ORD defines the requirement. OICW and OCSW reflect their lethality criteria by requiring specific levels of probability of incapacitation at different ranges. The Striker requires a fragmentation distribution within

[17]U.S. Special Operations Command, memorandum for Commander in Chief, U.S. Special Operations Command, Subject: “Amendment to the Approved Advanced Lightweight Grenade Launcher (ALGL) Operational Requirements Document (ORD)” , n.d., (11)

several meters of the burst point with penetration requirements and fragmentation coverage.

Suppression is mentioned in each ORD, but with no defined levels of performance. Given the accuracy requirements and lethality requirements, it can be assumed that all three will be very good at suppression. But the suppression requirements lack any definition or criteria for effectiveness. In this context, it is doubtful that suppression will be modeled and doubtful that it will have any actual test criteria.

Section IV
Effectiveness Methodologies

The effects of gunpowder – that major agent of military activity- could only be demonstrated by experience. Experiments are still being conducted to study them more closely.

It is, of course, obvious that an iron cannonball, impelled by powder to a speed of 1,000 feet per second, will smash any living creature in its path. One needs no experience to believe that. But there are hundreds of relevant details determining this effect, some of which can only be revealed empirically. Nor is the physical effect the only thing that matters: the psychological effect is what concerns us, and experience is the only means by which it can be established and appreciated. In the Middle Ages firearms were a new invention, so crude that their physical effect was much less important than today; but their psychological impact was considerably greater.

Clausewitz, On War[18]

Understanding Effectiveness

Clausewitz's quote provides the basis for this section. Not only is it necessary to understand the physical effects of a weapon system, but the psychological effects are part of the overall effectiveness as well. The purpose of this section is to provide the past and current methodologies as a base source for the reader and the proposal in Section IV. It is critical to understand what is meant by probability of incapacitation so the previously presented ORD's in Section II are understood. This section will go into significant detail on the Sperrazza-Kokinakis report and will describe other models currently being used. In addition, this section will also look at some other considerations regarding effectiveness.

Probability of Incapacitation

[18] Clausewitz, Carl Von, *On War*, Trans. Michael Howard and Peter Paret. Princeton: Princeton University Press, 1989, 170

In January 1965, William Kokinakis and Joseph Sperrazza published a now declassified report entitled *Criteria for Incapacitating Soldiers with Fragments and Flechettes: BRL Report No. 1269*. Working at the U.S. Army Material Command Ballistic Research Laboratories at Aberdeen Proving Ground, Maryland, this report was a milestone achievement and the genesis for methodology in evaluating incapacitation of soldiers based on empirical data gathered from a multitude of experiments. The first phase of the study was the conduct of experiments and the assessment of hypothetical wounds in terms of incapacitation conducted by the Biophysics Division, CRDL, and Edgewood Arsenal. The purpose of the experiments was to determine the depth and lateral extent of a hypothetical wound tract in a soldier. To do this, flechettes and projectiles were fired at different velocities into different types of anatomical components of Angora goats, whole live goats, and occasionally human skulls and limbs. Measurements of retardation of the velocity of projectiles as it penetrated through different thicknesses of components were made and autopsies would then be performed. The data was then provided to medical assessors who then estimated the physiological effects in soldiers subjected to the hypothetical wound tracts from random impacts. Based on this information, a set of wound classes was established. The following table from the report provides these wound classes.[19]

Typical Wound Classes[20]

<u>Description</u>
SKULL; Severe fragmentation or depressed fracture
BONE; with concurrent cardiovascular wound
HAND; any wound at this velocity

[19] Kokinakis, William and Sperrazza, Joseph *Criteria for Incapacitating Soldiers with Fragments and Flechettes: BRL Report No. 1269* (3-10)
[20] ibid (10)

URETER, URETHRA, and URINARY BLADDER; puncture wound with leakage
NERVE; with concurrent cardiovascular damage
LUNG; puncture with small blood loss

The next step in their research was to relate the wound classes to degradation of performance tasks of the soldier. The focus of the incapacitation was directly correlated to the functionality of the limbs of the soldier and hence his performance capabilities. Their report states "Of crucial significance to the study are the judgments made by the medical assessors on the relationships between behavior of the limbs and the ability of the wounded enemy soldier to carry out his assigned task. The table represents the best estimates of these relationships and is based on a consensus of opinion of medical assessors and of combat personnel. Each discrete level of disability refers to, "on the average", the decrease in effectiveness of the soldier."[21] In general, the longer the post wound time, the higher the level of incapacitation becomes as noted in table 1.

Table 1

Percent Disability Vs. Functional Group for Four Tactical Situations[22]

Each		Functional	Percent Disability			
Arm	**Leg**	**Groups**	**Assault**	**Defense**	**Reserve**	**Supply**
N,N	N,N	I	0	0	0	0
N,N	N,F	II	50	25	75	25
N,N	F,F	III	75	25	100	50
N,N	N,T	IV	100	50	100	100
N,N	T,T	V	100	50	100	100
N,F	N,N	VI	50	25	75	25
F,F	N,N	VII	75	50	100	50
N,T	N,N	VIII	75	75	100	75
T,T	N,N	IX	100	100	100	100
F,F	F,F	X	75	75	100	75
F,F	F,T	XI	100	75	100	100
F,F	T,T	XII	100	75	100	100
F,T	F,F	XIII	100	100	100	100

[21] ibid (11)
[22] ibid (13)

T,T	*T,T*	*XIV*	*100*	*100*	*100*	*100*
N,N	F,T	XV	100	50	100	100
N,F	F,F	XVI	75	50	100	75

Code- N No Effect
F Loss of fine muscular coordination
T Total loss of extremity function

The next table lists a total of 16 disability or functional areas, which is based on the effects of the limbs, Sperrazza/Kokinakis then provided a table that correlated the wound class and the functional group over post wounding time.

Table 2

Effect of Post-Wounding Time on Assignment of Functional Group

Wound Class Description	**30** sec	**5** min	**30** min	**12** hrs	**24** hrs	**5** days	**Average** Disability
Skull	*XIV*	*XIV*	*XIV*	*XIV*	*XIV*	*XIV*	*100%*
Bone	VI	X	XIV	XIII	XIII	XIII	
Bone, Leg	IV	XV	XI	XI	XI	XI	
Hand	VI	VI	VI	VI	VI	VI	
Ureter, Urethra, Bladder	I	I	I	X	XIV	XIV	
Nerve	VI	X	XIV	X	X	VI	
Lung	I	III	X	X	X	XIV	

They then used an average man, 69 inches tall and 155 pounds, divided into 108 horizontal cross sections ranging from 1.2 cm to 2.6 cm in thickness. They then used geometrically shaped projectiles of specific mass and velocity to determine the effects on the body based on six shotlines placed at 60 degree intervals around the body. The average would then provide a particular percentage level of incapacitation. It is noted that this is not a “probability of incapacitation” but rather the “average level of incapacitation” based on a random hit with a specific projectile defined in mass, striking velocity, and shape.

The formula derived from their effort is what has become known as the formula for probability of incapacitation.

$$P_{hk} = 1 - e^{-a(mv^{3/2} - b)^n}$$

Whereas:

P_{hk} is Probability of Incapacitation or also P_i

"e" is the base of the natural logarithm

"m" is the weight of the fragment

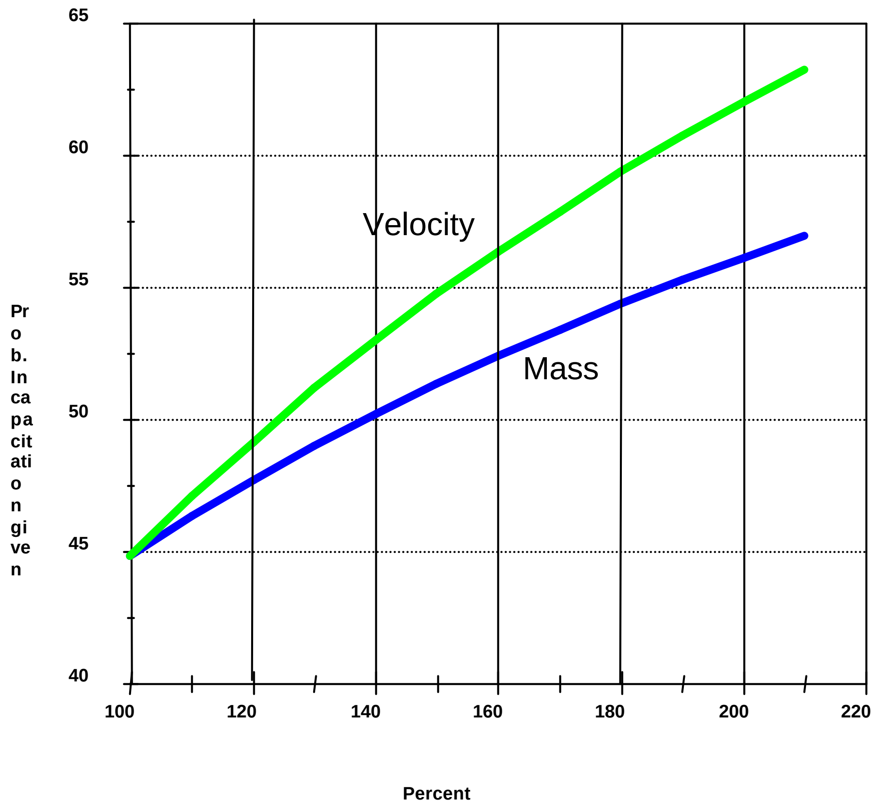
"v" is the striking velocity

"a, b ,and n" are coefficients that equate to time after wounding and the tactical role. These coefficients are relative to the exact scenario that the incapacitation calculation is being determined. For example, the intended targets clothing, protection, and task conducting must have these coefficients available for the equation.

3/2 is the variable that provides analysis based on the whole body

Figure 1

Depiction of Velocity increasing Performance More than Mass[23]



[23] Primex Technologies "Effectiveness Concepts and Computations" March 1998. Presented to DRPM AAA 24 March 1998, (slide 5)

The BRL Report 1269 included probability of incapacitation curves for various projectiles at various velocities to determine their effects on the human body. The formula for probability of incapacitation has been used extensively in subsequent modeling efforts as vulnerability and lethality codes have been written.

Operational Requirements-based Casualty Assessment (ORCA) and other methodologies

Since the initial Sperrazza Kokinakis work, computer programs have utilized their work as a fundamental aspect in determining probability of incapacitation. Current programs in use are Ballistic Dose, Computerman, and ORCA. Glenn Romanczuk and Christopher Pitts did a superb paper on incapacitation methodologies and is included in Appendix A as a supplement to this paper for more information should the reader desire. The program that is significant for this paper is ORCA.

ORCA incorporates several models, algorithms, and scoring systems to determine the functional capabilities of an individual following an injury. Since it is a conglomeration of subset models, it can assess penetrating injuries, non-auditory blast overpressure injuries, blast pressure induced auditory injuries, rapid acceleration injuries, laser eye injuries, thermal and burn injuries, and chemical injuries. The process of developing ORCA attempted to incorporate operational casualties with medical casualties. The model utilizes the civilian medical communities standard measure of individual anatomical injury severity methodology for Abbreviated Injury Score, Injury Severity Score, and others. One of the key features of ORCA is correlating the various types and levels of injury to the impairment of an individual's capabilities and recorded

as an Elemental Capability Vector. There are 24 elemental capabilities elements grouped into six general categories.[24]

Categories of Elemental Capability Elements[25]

Visual- Vision is critical for almost every imaginable task, including battlefield surveillance, driving a tank, or loading weapons.

Auditory- Hearing is measurable in decibels for two threshold frequencies. Crewmembers likely to require hearing capability include communication personnel, combat vehicle crewmembers, infantry soldiers and pilots.

Mental- Cognitive, visual auditory, and psychomotor mental processing refers to the brain responses needed to interpret or understand the stimuli received by the senses. The ability to reason and make decisions is critical for many tasks in the field.

Vocal- Vocal capability is measured by the amount of vocal power needed and speech intelligibility. The ability to communicate can be important on the battlefield as well as in communication activities.

Physical- Physical tasks are broken down by body segment. Strength and movement capabilities of the legs, arms, hands, torso, and neck are measured in the ECV. Minor physical tasks, such as pushing a button or turning a knob can be modeled as well as major tasks, such as walking, climbing, pushing or pulling, or swimming.

Endurance- Other capabilities, such as endurance, balance, and a sense of touch, are modeled in the ECV. Endurance will play an important role in determining casualties because many injuries can affect the blood or oxygen supply to the body.

ORCA does have many similarities with the Sperrazza Kokinakis methodology. ORCA characterizes an injury when it occurs and continues to recognize that the injury's effects change over time. ORCA calculates the time parameters as immediate, 30 seconds, 5 minutes, one hour, 24 hours, and 3 days. The unique capability ORCA offers is that it then relates the injury over the time parameters to an operational casualty related

[24]Neades, David N., Klopcic, Dr. J. Terrence, Davis, Dr. Edward G., "New Methodology for the Assessment of Battlefield Insults and Injuries On the Performance of Army, Navy, and Air Force Military Tasks", U.S. Army Research Laboratory, Survivability and Lethality Directorate, Aberdeen Proving Ground, MD, n.d. (28-5)

to a specific MOS/Job Task. A portion of the current library of MOS's are provided as an example in Figure 2 and Table 3.

Figure 2

ORCA Input Screen for Penetrating Injury [26]

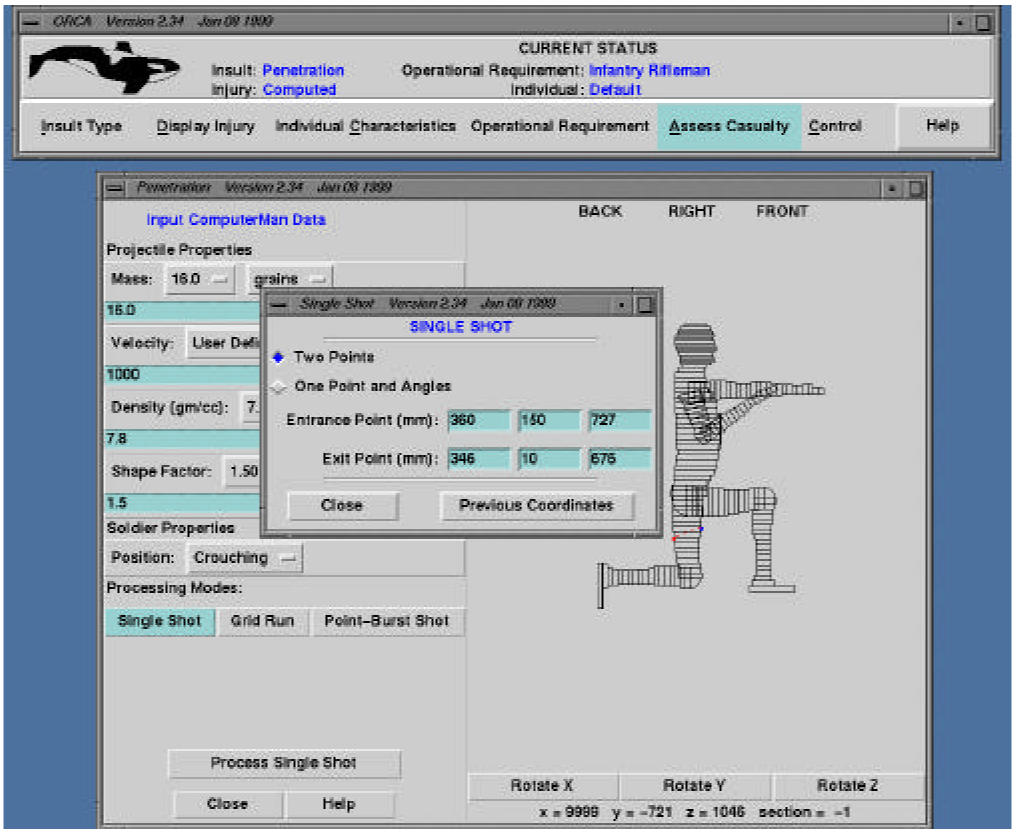


Table 3

Job	Tasks	Task Elements[27]
Infantry Rifleman	64	266
AH64 Apache Pilot	86	377
Combat Engineer	42	315

[25] ibid, (28-5,6)

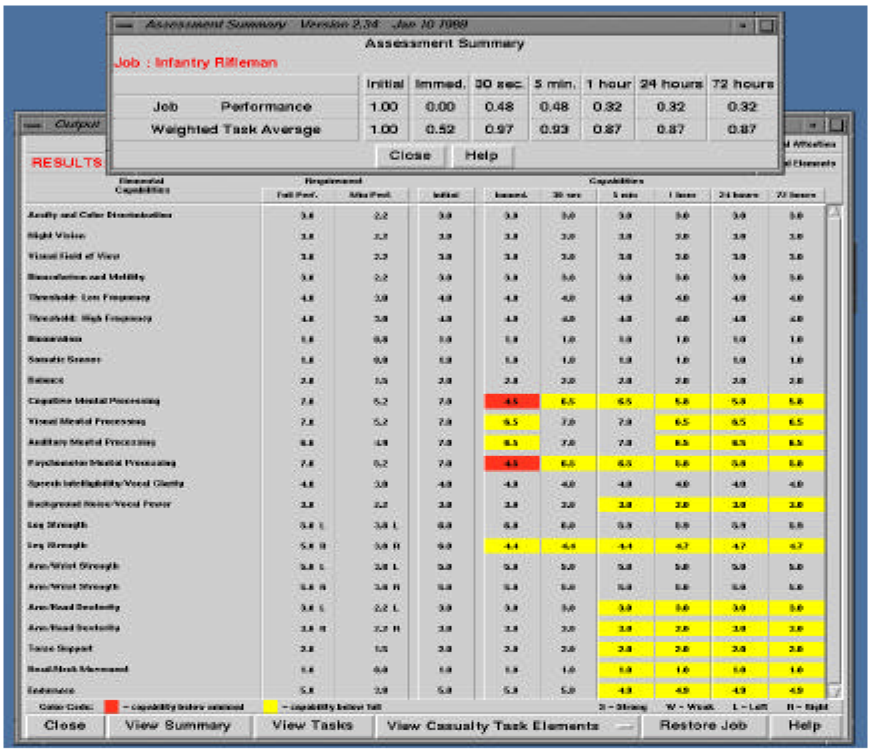
[26] Neades, David N., Klopcic, Dr. J. Terrence, Davis, Dr. Edward G., "The Operational Requirement-based Casualty Assessment (ORCA) Model", presentation for Author, 16 November 2000

[27] Neades, David N., Klopcic, Dr. J. Terrence, Davis, Dr. Edward G., "New Methodology for the Assessment of Battlefield Insults and Injuries On the Performance of Army, Navy, and Air Force Military Tasks", U.S. Army Research Laboratory, Survivability and Lethality Directorate, Aberdeen Proving Ground, MD, n.d. (28-11)

Artilleryman (M-109 Gunner)	34	173
M1A1 Abrams Gunner	99	706
Combat Pilot (F-18)	136	555
LAV Crewman (Driver)	38	227

<u>Figure 3</u>

ORCA Performance Assessment Screen depicting tasks that would be impaired from an injury.[28]



There are two recognized limitations of this model for determining the effectiveness of airburst munitions. The first limitation is the library is associated with friendly MOS's/job's and their associated tasks. The question then becomes, does the enemy

[28] Neades, David N., Klopcic, Dr. J. Terrence, Davis, Dr. Edward G., "The Operational Requirement-based Casualty Assessment (ORCA) Model", presentation for Author, 16 November 2000, slide 17

infantry soldier have the same tasks as a U.S. Army infantry soldier (11B)? In the requirements section for the weapon systems such as OICW and OCSW, is the threat represented available in the ORCA database? Can it handle asymmetric threats such as have been seen in Somalia and other places?

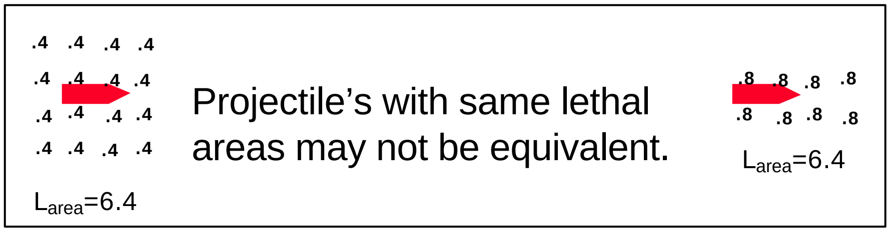
The second limitation of the ORCA model is characterizing the tasks. For example, in a Sperrazza Kokinakis defined 30 seconds assault criteria, would we expect an infantry soldier to be able to do 64 tasks? Obviously not. Given that, what would the tasks of an enemy soldier be in the 30-second assault? Those tasks should then be the ones by which the effectiveness is then modeled and weighted to determine the enemy soldiers capabilities following an injury.

These are items that the ORCA team at ARL is working on in the enhancement of the ORCA model. Once these are provided in the model, ORCA will be relevant in the analysis of airburst munition effectiveness.

Lethal Area

Lethal area is a term that is used to describe the notional lethal performance of a projectile. The lethal area presented does not necessarily reflect the projectiles true performance because it neglects the fragment pattern distribution. The units of area are meaningless and the computations are different based on fragment sizes and personnel postures.

Figure 4
Lethal Area Comparison[29]



Suppression and the non-physical effects

Suppression of enemy infantry is as important in the operational environment as defeating them. Dr. D.J.J. Jaya-Ratnam, WS4 Guns and Warheads Department, DERA Fort Halstead, UK, brings up two issues relative to new concepts which enable soldiers to hit and incapacitate more easily through the use of new technology. Although primarily focused in small arms, his analysis is directly attributable to medium caliber as well. His argument is as follows:

> "Firstly, although weapons have become very much more lethal, over much longer ranges, the actual rate of casualties has not increased significantly. This is due to the fact that soldiers do not wait around to be shot; they run, take cover and shoot back. Thus any improvement in weaponry usually results in a corresponding change in tactics and enemy equipment to compensate (with occasional exceptions such as the American Civil War and the First World War- both of which saw heavy casualties).
>
> Secondly, despite the relatively low number of casualties caused, battles are still won and lost. This would suggest that whilst modern weapons are not effective at causing casualties, they may still be effective at winning battles – 4000 rounds per casualty sounds wasteful, but is 40000 rounds per engagement won not acceptable?
>
> The answer to this seeming paradox is the fact that most ammunition is used to suppress the enemy, in order to allow ones own troops to get close enough for their weapons to actually be effective in causing casualties. Thus in order to gain a full

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[29] Primex Technologies "Effectiveness Concepts and Computations" March 1998. Presented to DRPM AAA 24 March 1998, slide 16

appreciation of the effectiveness of a particular small arm system in combat, it is necessary to include its suppressive capability in any assessment."[30]

The NATO STANAG 4513: The Definitions of Incapacitation and Suppression defines suppression as "…when he is unable or unwilling to carry out his task effectively, because of the actual or perceived threat, or because of fear (in particular of being wounded)"

Dr. Jaya-Ratnam provides the concept of Perceived Probability of Incapacitation (PPI) or Perceived Risk (PR) where a soldier makes a subconscious decision that his PPI is higher than his actual PI, he will take action then to reduce his PPI and is then suppressed. He points out though that each soldier's PPI is constant whereby different weapon systems can be compared. His analogy that a veteran will usually have a PPI closer to his actual PI whereas a new recruit will have a PPI much higher than his actual PI. An example is a system with a low PI will probably result in a low PPI and the soldier will not likely be suppressed. A weapon with a high PI, such as artillery, has a very high PI so the soldier's PPI will also be high and thus he will be suppressed due to the high risk. Dr. Ratnam also points out that a weapon, such as Heavy Machineguns, is relatively inaccurate but has tremendous terminal effects, noise, and flash and therefore the soldiers PPI is much higher than his PI. Developing a suppression criteria for a weapon system then provides a methodology to determine how to "maximize the suppressive effects, for a given lethal effect.(which is somewhat easier than constantly trying to improve terminal

[30] Jaya-Ratnam, Dr. D.J.J., "Close Combat Suppression: Need, Assessment and Use" Paper presented at the 34th NDIA Guns and Ammunition Symposium, 26-29 April 1999 Monterey, CA: electronic copy , 1

effects in the face of body armor and field fortifications)"[31] The second consideration for suppression criteria is duration of suppression.

The Close Combat Suppression Model (CCSM) provides an equation to determine a soldier's PPI based on the soldier's actual PI, aural stimuli, and visual stimuli.

$$\mathbf{PPI} = f\mathbf{(PI, ASF, VSF)}$$

Whereas: PI is the Probability of Incapacitation
ASF is the Aural Signature Factor (relative to baseline)
VSF is the Visual Signature Factor (relative to baseline)

"The terms for ASF and VSF account for the soldier's awareness of being under threat, and are based on noise, flash, and dust caused by the ammunition, relative to those caused by the baseline system"[32]

The Suppression Measurement Methodology (SMM) is used to determine if a weapon system is meeting the required level and duration of suppression. The CCSM must first be calculated to determine the PI necessary to cause the PPI to exceed the threshold and suppress the target. Then the area where the PI must be determined to find the Suppressive Area (SA) of the round. This is designed in methodology for a direct fire small arms system and may take some additional work to extrapolate the requirements for a medium caliber airburst munition. However, it can be reasoned that some of the same criteria could apply. Instead of comparing weapon systems though, we are actually comparing munitions effectiveness in a suppressive role.

The U.S. Army conducted suppressive experiments with a variety of weapons from M-16 rifles up to 105mm main tank gun focusing on proximity and volume of fire. In this experiment, suppression was divided into 3 catagories: physical suppression, unreasoned suppression, and reasoned suppression. The report used the following definitions:

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[31] ibid, 4
[32] ibid, 5

Physical Suppression- degradation of performance of an individual or unit due to physical incapacitation such as death, injury, obscuration, or other physical constraints.
Unreasoned Suppression- temporary degradation in the quality of performance of a individual or unit due to immediately uncontrolled psychological or physiological factors such as panic, fear, fatigue, etc.
Reasoned Suppression- temporary degradation in the quality of performance of a soldier or unit due to avoidance of a perceived threat from enemy weapon systems.[33]

While the Army experiment covered a diverse spectrum of calibers, it was apparent with every caliber that had a ground burst and airburst capability, the airburst round provided a noticeable increase in suppression. This was true for 4.2 inch through 8 inch munitions and was based solely on radial miss distance of the projectile to achieve a 0.9 and 0.5 probability of suppression.[34] Based on this data, it would be reasonable that suppressive effects from medium caliber airburst will be much greater than medium caliber point detonating munitions based solely on radial miss distances.

[33] U.S. Army Combat Developments Experimentation Command, "Suppression Experimentation Data Analysis Report", Fort Ord, CA: April 1976 (1-1)
[34] ibid, (2-3)

Section V
Recommendations For Medium Caliber Airburst

In any effectiveness evaluation of a munition, there is an attempt to create or use a methodology that equates to the notional method of employment of the weapon system. Effectiveness against material type targets, such as BTR's, trucks, and masonry structures, are quantifiable. The true difficulty lies in the evaluation of munitions against infantry and personnel. Doctrinal squad formations of the threat are usually templated as a target to evaluate. The dilemma for airburst munitions becomes, is there a template for an infantry squad in asymmetric warfare or against the myriad of potential threats in the 2015 timeframe? The other part of the dilemma is the infantry unit's mission. For the most part, a good assumption is that any offensive or defensive operation of utility will usually require mass or synchronization to be effective.

The dilemma then begins again. What type or size unit should the munition be tested against? Then the next criteria is to assess the will and strength of the enemy. For example, with a mission similar to the one the Marines and Army faced in Saipan with a determined enemy force to resist to the end will require more ammunition than an enemy such as the Iraqi soldiers in Desert Storm who surrendered quickly. If viewed from this sense, the worst case scenario is a very determined enemy force.

The other consideration is the threat level of the personal protection of the individual soldier. This may be state of the art vests and helmets, to lower levels of protection, to no protection at all. A determination has to be made on the protection level required to defeat in order to determine the realistic requirements the munition must defeat. Included in the will to fight is the level of training and experience of the threat soldier. A force that

can fight under fire, handles casualties well, and remains focused on the mission is a very formidable force. A lower level of lethality against a very professional soldier will have less effectiveness than a high lethality munition. Once again, we return to the issue of lethality and how it is determined.

Referring to previous definitions of lethal area and incapacitation, inconsistencies can create a false sense of effectiveness against infantry or create a scenario where the estimate of munition resources is less than the actual required need, which can lead to disaster. Models used in the predictions of effectiveness can lead to erroneous battlefield ammunition requirements if the models are not "valid" for the operational scenarios.

In thinking about the dilemma, the idea may be to handle the evaluation by a large diverse matrix of possibilities. Given this approach, what is the endstate? A large matrix that at best now reverts to an intuitive approach to the answer or a sum of the matrix to determine a total effectiveness value which will likely prove to be rather meaningless. What about an approach that attempts to merge scientific analysis, with its limitations, with intangible or unquantifiable aspects into one methodology? The author proposes this as a recommendation for the requirements generation process, ORD process, munition development process, operational test and evaluation process, and the live fire analysis process. Perhaps this methodology attempts to remove some of the subjectivity referred to in the Sperrazza Kokinakis paper. Or, it allows for some subjectivity with a common sense approach.

Recommendation For An Operational Effects Based Approach

An approach to alleviate some of the difficulties encountered in effectiveness methodologies and effectiveness criteria may be to create a matrix based on all the

desired characteristics of the airburst munition. The proposal is relatively simple in theory. First, we must know how we plan to employ our airburst munitions that we covered in section II of the paper. This provides industry and the government with a common employment /operational picture. The second part of the approach is to determine what degree of effectiveness is desired and /or required. By this I mean, is it imperative that the enemy be at some level of incapacitation or suppression. What are all the intangible elements that should be required?

I propose to use seven classes of operational effectiveness. Each class contains some of the many attributes that are desired in an airburst munition. Each class has within it a "window" of performance based on effects.

Table 4
Physical Criteria

CLASS	CRITERIA	METHODOLOGY USED
1	No effect on Combat Functions. Zero incapacitation. P(I) of 0. Effects- still fully functional.	ORCA, ICEM, Live Fire Results, SME Analysis of Firings and Results
2	Less than 20% loss of combat functions. Light incapacitation P(I) 1-20% Less than 20% loss of tasks Effects- Can perform all functions with slight degradation Can still use legs and arms No 1st Aid Required/ Self Aid Only	ORCA, ICEM, Live Fire Results, SME Analysis of Firings and Results
3	Limited Combat Functions. Limited Incapacitation P(I) 21-44 Effects- Can perform 60% of combat functions. Limited use of legs and arms. Requires limited First Aid.	ORCA, ICEM, Live Fire Results, SME Analysis of Firings and Results
4	Residual Incapacitation. Probability of Incapacitation of P(I) 45-59 Effects- Can perform 40% of combat functions Doubtful use of legs and arms Requires First Aid	ORCA, ICEM, Live Fire Results, SME Analysis of Firings and Results

5	Functional Incapacitation P(I) 60-75 Can perform 10% of combat functions Immobile. Requires constant first aid.	ORCA, ICEM, Live Fire Results, SME Analysis of Firings and Results
6	Extreme Incapacitation P(I) 76-89 Effects- Can not perform any function except a last self defense weapon at point blank range Immobile Requires immediate first aid to save life	ORCA, ICEM, Live Fire Results, SME Analysis of Firings and Results
7	Deadly Incapacitation P(I) 90-100 Effects- Can not perform any function Death imminent	ORCA, ICEM, Live Fire Results, SME Analysis of Firings and Results

One of the inherent difficulties of classifying effectiveness in categories will be in combining the effects of physical criteria and mental criteria. The chart above portrays a measurable methodology for the physical effectiveness of an airburst projectile. It does not appear that the mental effectiveness should be added to these criteria. An example of this problem would be a munition that caused light incapacitation but created a high Perceived Probability of Incapacitation (PPI). Given this scenario, an enemy target may still be physically capable of functioning, but may perceive his potential risk as to high to actually accomplish his mission or functions based on the suppressive effects. Given this dichotomy, it seems prudent that there should be two categories. The problem then becomes defining the enemy's mental suppressive state.

Table 5
Mental Criteria

Class	Type	Description and characteristics
1	Unaffected	Ver small visual or aural signature. No casualties. Low probability of being hit by fragmentation. Low perceived probability of incapacitation.
2	Apprehensive	Noticeable visual and aural signature. Minor casualties in

		squad. Some reluctance to take risk. Experience level will determine level of apprehension. If casualties are minor, will have acceptable level of risk and continue with combat functions.
3	Doubtful	Definitive visual and/or aural signature. Apparent danger, medium to high perceived probability of incapacitation. Reluctant to take risk; Indecisive. Will try to determine if there is other imminent danger that may be of greater risk. Casualties are not severe but have significant injury.
4	Fearful	Significant visual and/or aural signature. Single major casualty in squad that requires first aid and medevac; some minor casualties. Demonstrated lethal effects. Perceived probability of incapacitation is high. Very reluctant.
5	Scared	High level of visual and/or aural signature. Definite danger, high perceived probability of incapacitation. Multiple casualties in squad requiring first aid and medevac. Shock, bewilderment. Situation out of control. Loss of squad mission mentality.
6	Frozen	High level of visual and/or aural signature. Fatal and multiple serious casualties. Chaos. Immobile. Complete loss of mission mentality and structure.

If Dr. Ratnam is correct, then there will certainly be a spectrum of suppression as there is a spectrum of each soldier's perceived risk. The suppressive categories should ideally match up with the lower categories of physical effects. It would seem meaningless to prescribe a suppressive effect to a munition that is capable of providing the physical effects that reduce or eliminate his ability to function or complete his mission because the effects are already apparent. However, this is only true if in fact the airburst projectile in fact detonated at the prescribed point in space relative to the intended target. Or given an 8 man squad, it would be unreasonable to assume that every one in the squad would be at the same level of ineffectiveness by category. Given this, it would be meaningful to apply a physical standard to those within the physical effectiveness area and a mental effectiveness standard to the entire squad. Therefore, an intended squad target should

have a requirement of potential physical effects and a requirement of potential mental effects.

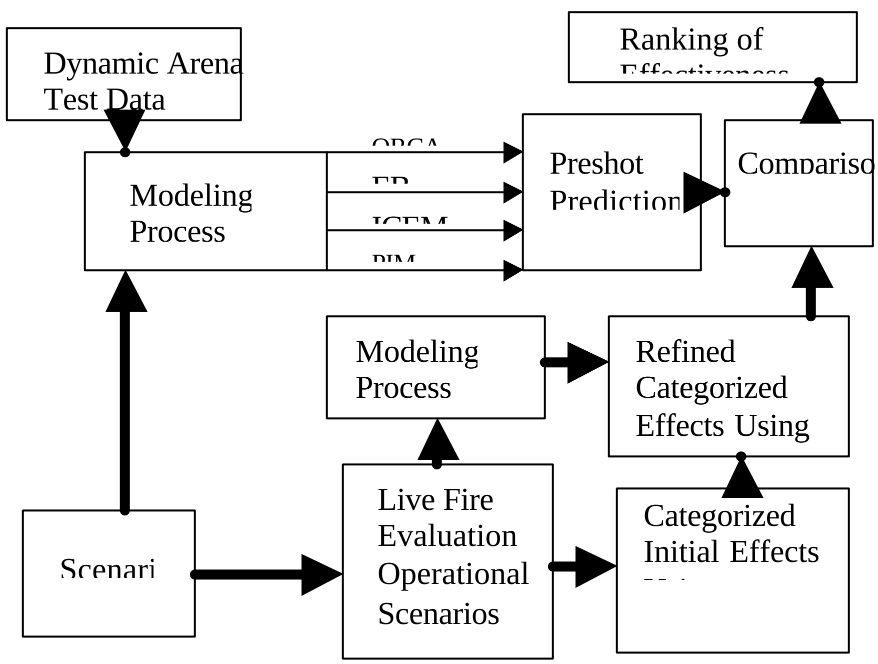
An example of this may be that an 8 man squad is engaged by an AAAV at 1700 meters. The gunner clearly sees 5 of the 8 squad members, but does not know where the possible three other members are. Perhaps out of the field of view, perhaps the squad is reduced to only 5 members, but let us assume from an operational effectiveness criteria standpoint that all eight are present. The area of space the squad occupies is the 10 meter by 50 meter area. The gunner picks an aim point within the squad area for a three round burst. Since there are several ways to engage a specific type of airburst munition for a squad based on the munitions capability, we can also assume that the gunner is a “string of pearls” or a specified airburst detonation pattern within the squad area that maximizes the effective area.

For this example, let us assume one round has very lethal, large fragments capable of penetrating protective vests on any soldier within 8 meters of the burst point, except towards the rear area of the projectile. The round has an appreciable amount of explosive fill to propel these large fragments. In addition to the explosive fill, there is some zirconium for fire starting. The end result being a deafening noise, brilliant flash, explosive concussion, and deadly fragmentation permeating through the squad area followed by two additional rounds within one second detonating the same way. In this scenario, assume the squad had relatively good dispersion and that 5 of the 8 men in the squad were hit. Using the above categorization, let us assume that two of the men were class 6, two class 5, one class 4, one class 2, and two class one. As a squad, they are now at a minimum 50% effective because four of the members are ineffective. Of the

remaining four, one is marginally effective, one mostly effective, and the last two are totally effective. Yet, given this situation, would the last three or four continue or are they now suppressed and basically ineffective? Let us review their perception of the situation. Three rounds detonated in their area, which would let the soldier, know they were under observation and directly fired at. They do not necessarily know where the round came from since the firing platform was 1700 meters away. They did not hear the sound of the gun going off because it would have arrived after the rounds functioned in airburst mode. There may or may not have been any visual que for barrel smoke. They do not have any organic weapon capable of a 1700 meter engagement. Immediate action for the infantry squad in this scenario would be to go to the prone position and seek cover. At the same time, the effective soldiers must assess their fellow squad members that are injured. Do they go to them and administer first aid, do them pull them to cover, or do they stay where they are in their perceived relative safety? Is their perceived probability of incapacitation high or low? In this case, the effective soldiers may decide to risk relative safety to help one of the injured soldiers, or may decide to remain in his perceived relative safe spot, or he may continue on with his mission. If he chooses the first or the third choice, he presents himself as a target again to the airburst munition. If he decides to remain in relative safety without firing his weapon, he also is unaware of what is happening on the battlefield or at least not directly contributing to the battle. His options are rather limited. He may withdraw, defend, delay, or surrender. The preferred answer is surrender in this case.

Methodology to Support Operational Testing

The flow chart below proposes the process by which the evaluations should be conducted. The flow chart is similar to what is done currently in many aspects. The major differences are in how the effects of live fire evaluation are refined with the modeling support. The goal is to provide the effectiveness of an airburst munition utilizing the proposed categories in this paper, evaluate the live fire results, compare them with modeling results, and provide a feedback loop that begins to bring both results closer together. Regardless of the modeling outcome, the flowchart will allow a munition to be placed into specific categories and be compared with others in order to determine which airburst munition meets all or most of the requirements.



The overall process involves several different organizations from all the services. The validity of the models then becomes more than just the accreditation process that every model used by the Joint Technical Coordinating Group for Munitions Effectiveness must

undergo. Since the JTCG/ME is providing models that will allow the operating forces to determine the effectiveness of their weapon systems, then the models must support what the live fire results would predict.

OTHER AIRBURST CONSIDERATIONS

Beyond lethality and effectiveness of an airburst munition, there are many other factors that will account for the lethality of the munition. Really the munition's job is to get to the correct three-dimensional point in space and detonate. In all respects, it must do this reliably and consistently. The other parts of the equation are the fire control solution and the gunner. The fire control system must account for a variety of inputs for the correct solution. The accuracy of the laser return from the target, the internal and external ballistics of the projectile, as well as a myriad of other considerations adds to what is termed the error budget. However, this creates another area of effectiveness as a function of accuracy.

SECTION VI
CONCLUSION AND SUMMARY

The paper has presented an overview of airburst munitions, the target scenarios, similar airburst systems, current effectiveness methodologies, and a proposed methodology for evaluating airburst munitions. The proposed solution can or should be adopted as the methodology for airburst programs for both domestic users and foreign. Additional research will be required to provide more detail to the proposed criteria. However, the proposal creates a skeleton for a new methodology. NATO STANAG 4513 is of little use in really creating a standardized methodology for evaluation purposes. Current methodologies do not encompass all the particular requirements an airburst munition should have. In addition, there are three actual acquisition programs pursuing airburst technology in direct fire weapons. Then there are the high velocity medium caliber airburst users. The one thing all of these share in common is the threat. All will be used on the same battlefield. Their primary target is enemy infantry. Yet the requirements do not reflect exactly how we intend to evaluate the munition or the weapon system. If the weapon systems are evaluated only by probability of incapacitation, then we are limiting the use of that weapon to only the physical aspects of effectiveness. The mental aspects are completely ignored. There are no suppressive requirements in any of the ORD’s. In essence, the requirements for effectiveness are vague and are open to interpretation. However, the proposed criteria presented in Section V of this paper creates a window. Within this window, there is a performance that both the Government and Industry can understand and measure the product against. Is there still a bit of interpretation involved in the process? The answer is “Yes”? Will the interpretation be

able to stay within a category? The answer should be yes as well. If the answer is "No", then how could the original criteria ever have been agreed upon during the final test phases? My recommendation is that the Marine Corps AAAV Program and the Navy's LPD-17 Program utilize this process in their comparative tests of several medium caliber airburst munitions. In addition, it is recommended that an Airburst Effectiveness Working Group be composed of OICW, OCSW, Striker, AAAV, and LPD-17 regarding the envisioned threat, requirements, modeling, and test methodologies. The group should also be composed of industry representatives as well. The author will conduct additional research in the future on this topic.

The end result is that airburst munitions are the best munitions for the military. In the end, the Joint Vision is increased lethality on the battlefield. Force protection is increased and logistics are decreased. The airburst munitions provide more options to the warrior who must decide when to fire and what to fire. The end result is that the best product is fielded so that the Marines, Sailors, Soldiers, and Airmen are confident and able to win on tomorrow's diverse battlefield. Today is the time to make this a reality!

LPD-17	Landing Platform Docked – 17 (U.S. Navy Amphibious Ship Class)
MPLD-T	Multipurpose Low Drag – Traced
m	meter
mm	millimeter
m/sec	meters per second
MCIA	Marine Corps Intelligence Activity
MCCDC	Marine Corps Combat Development Command – Quantico VA
MK 44	Mark 44
MK 46	Mark 46
MPLD-T	Multipurpose Low Drag - Traced
MIL-STD	Military Standard
NAMMO	Nordic Ammunition Company (A cooperative merger of Norway's Raufoss Ammunition, Sweden's Bofors Ammunition, and Finland's Patria Ammunition Companies)
NDIA	National Defense Industrial Association
NGIC	National Ground Intelligence Center
NSWCCD	Naval Surface Weapon Center Crane Division, Crane, IN
NSWCDD	Naval Surface Warfare Center Dahlgren Division, Dahlgren VA
(O)	Objective
PD	Point Detonating
PM	Program Manager
Primex	Primex Technologies (U.S. Ammunition manufacturer headquartered in St Petersburg, FL with major facilities in Marion, IL; St. Marks, FL; and Downey, CA. Operations in Downey conduct most of the Airburst R&D effort)
OCSW	Objective Crew Served Weapon (25mm Airburst-Primex)

ORD	Operational Requirements Document
Oerlikon	Oerlikon Contraves Pyrotec (Swiss Ammunition Company headquartered in Zurich, Switzerland)
OICW	Objective Individual Combat Weapon (20mm Airburst-Alliant)
ORCA	Operational Requirements-based Casualty Assessment
PASGT	Personnel Armor System, Ground Troops
PDRR	Program Design and Risk Reduction
$\mathbf{P_{(h)}}$	Probability of Hit
$\mathbf{P_{(h/s)}}$	Probability of Hit given a Shot
$\mathbf{P_{(i)}}$	Probability of Incapacitation
$\mathbf{P_{(i/s)}}$	Probability of Incapacitation Given a Shot
PIMMS	Probability of Incapacitation Methodology for Masonry Sructures
WSESRB	Weapon System and Explosive Safety Review Board
(T)	Threshold
TP-T	Target Practice - Traced

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